Cleaner Street Sweeper Purchases

Project definition: The purchase of an alternative-fueled street sweeper in lieu of a typical diesel powered street sweeper. Street sweepers frequently have two engines: a main (on-road) engine and a smaller auxiliary (off-road) engine. Both engines can be powered with alternative-fuels. Also, street sweepers that meet the certification requirements of the South Coast Air Quality Management District's Rule 1186 have improved road dust collection efficiency and generate less PM10 during sweeping activities when compared to non-certified equipment.

How emissions are reduced: Emission reductions are the difference between the emissions associated with operating a typical new diesel sweeper compared to one that uses cleaner, alternative fuels. There are additional PM10 emission reductions associated with sweeper operations if the sweeper is PM10 efficient and certified to Rule 1186. The methodology provides default PM10 benefits to account for Rule 1186-certified sweepers.

(There are additional benefits associated with a reduction in entrained road dust from vehicular traffic subsequent to sweeping operations; however, these benefits are difficult to quantify due to variability in roadway conditions and traffic volumes. Typically, alternative-fueled sweepers will be cost effective without consideration of these benefits.)

Need to know:
Funding dollars
Annual fuel usage
Engine certification rates
Annual miles swept

Inputs	Default	Units	Comments
Funding Dollars (**Funding**)		dollars	
Effectiveness Period (**Life**)	10	years	
Annual Gallons of Fuel Used for the Main Engine (**Main Fuel**)		gallons per year	Fuel usage for the main (on-road) engine. Default is 2/3 of total fuel usage for the vehicle. (Default for total fuel usage is 30 gal/day for 250 days/yr or 7500 annual gallons.)
Annual Gallons of Fuel Used for the Auxiliary Engine (**Aux Fuel**)		gallons per year	Fuel usage for the auxiliary engine. Default is 1/3 of total fuel usage for the vehicle. If there is no auxiliary engine, enter zero.
Annual Miles Swept (**Miles Swept**)		miles per year	

Emission Factor Inputs for the Main Engine

	Default	Units	Default	Units
	Main EF Before		**Main EF After** **(optional certification rate)** **(alternative-fueled)**	
ROG Factor	N/A	g/bhp-hr	N/A	g/bhp-hr
NOx Factor	4.0	g/bhp-hr	2.5	g/bhp-hr
PM10 Factor	0.1	g/bhp-hr	0.1	g/bhp-hr

The benefits are typically from NOx and PM10 reductions. "Main EF Before" is the emission factor for a new diesel street sweeper. "Main EF After" is the emission factor for a new cleaner, alternative-fueled engine. The defaults for "Main EF Before" are from Table 5 and are based on engine certification rates for heavy-duty trucks (or buses) with GVWR of 14,001 to 33,000 lbs. Not shown in Table 5 is the PM emission standard of 0.1 g/bhp-hr. Defaults for "Main EF After" assume that the new engine is certified to 2.5/0.1 g/bhp-hr for NOx/PM.

Similarly, the emission factors below represent diesel versus alternative-fueled auxiliary engine emissions. The defaults for "Aux EF Before" are from Table 6 and are based on the off-road diesel engine (50 – 175 hp) NOx emission standard of 6.9 g/bhp-hr for year 2000. Not shown in Table 6 is the PM emission standard of 0.4 g/bhp-hr. "Aux EF After" factors assumes that off-road engines will be available to meet a cleaner, optional certification rate of 4.9 g/bhp-hr for NOx and 0.22 g/bhp-hr for PM. This emission rate is the off-road standard for year 2003.

Currently, there are no off-road engines certified to a cleaner, optional level; however, the methodology allows for potential benefits from cleaner off-road auxiliary engines to be included should they occur. If the auxiliary engine is an on-road engine, then the defaults are the same as for the main engine shown in the table above. If the auxiliary engine is a new diesel engine that meets year 2000 emission standards, then no reductions can be assumed because new diesel engines represent the baseline.

Emission Factor Inputs for the Auxiliary Engine

	Default		Units	Default		Units
	Aux EF Before			**Aux EF After**		
	Off-Rd	**On-Rd**		**Off-Rd**	**On-Rd**	
ROG Factor	N/A	N/A	g/bhp-hr	N/A	N/A	g/bhp-hr
NOx Factor	6.9	4.0	g/bhp-hr	4.9	2.5	g/bhp-hr
PM10 Factor	0.4	0.1	g/bhp-hr	0.22	0.1	g/bhp-hr

Emissions Benefit Factor for Rule 1186-Certified Sweepers

Rule 1186-certified street sweepers tested in July of 1999 had an average entrainment value of 109 milligrams per meter (mg/meter). During those same evaluations, the non-certified street sweepers had an entrainment value of 340 mg/meter. Based on these evaluations, the net benefit of using a Rule 1186-certified street sweeper is 231 mg/meter; however, this value has been reduced to account for the fact that the silt loadings used in the test are greater than typical paved road loadings. With this reduction factor and the appropriate conversion, the net benefit from using Rule 1186-certified street sweepers is estimated at **0.05 pounds/mile** of street sweeping. This benefit factor is used in the formula below to calculate reductions from sweeping with Rule 1186-certified street sweeping.

Formulas Units

Annual ROG, NOx, and PM10 Emission Reductions from the Cleaner Engines (**Engine Reductions**) =

[Main Fuel * (Main EF Before – Main EF After) +
Aux Fuel * (Aux EF Before – Aux EF After)] * 18.5/454 lbs/year

(Note: The factor, 18.5 hp-hr/gallons, is the energy consumption factor.)

Additional PM10 Emission Reductions from Rule 1186-Certified Sweepers (**Sweeping Reductions**) =

Miles Swept * 0.05 lbs/year

Annual Emission Reductions (**ROG, NOx, and PM10**) =

Engine Reductions + Sweeping Reductions lbs/year

Capital Recovery Factor (CRF) = $\frac{(1 + i)^n (i)}{(1 + i)^n - 1}$

where: i = discount rate (Assume 5 percent)
n = project life

Cost-Effectiveness of
Funding Dollars = (CRF * Funding) / (ROG + NOx + PM10) dollars/lb

Note: The Federal Highway Administration requests that emission reductions from CMAQ projects be reported as kilograms/day. The conversion is

(lbs per year) / [(2.2) (365)] = kilograms/day*

Purchase of Rule 1186-certified, CNG Street Sweeper

A city purchases a street sweeper certified to Rule 1186 that uses compressed natural gas (CNG). The sweeper has a GVWR of 32,000 lbs with a main on-road engine plus an on-road auxiliary engine (150 hp). The new engines are certified to 2.5/1.0 g/bph-hr for NOx/PM. The cost difference between a new cleaner sweeper and a new typical diesel sweeper is $40,000.

Inputs to calculate cost-effectiveness:

Funding Dollars (Funding) = $40,000

Effectiveness Period (Life): 10 years

Annual Gallons of Fuel Used by the Main Engine (Main Fuel): 5,000 gallons per year

Annual Gallons of Fuel Used by the Auxiliary Engine (Aux Fue): 2,500 gallons per year

Annual Miles Swept (Miles Swept): 10,000 miles (40 miles/day * 250 days/year)

Energy Consumption Factor: 18.5 hp-hr/gallons

Emissions Factors for Main Engine:

	Main EF Before	Main EF After
ROG Factor	not applicable	not applicable
NOx Factor	4.0 grams/ bhp-hr	2.5 grams/ bhp-hr
PM10 Factor	0.1 grams/ bhp-hr	0.1 grams/ bhp-hr

Emissions Factors for Auxiliary Engine:

	Aux EF Before	Aux EF After
ROG Factor	not applicable	not applicable
NOx Factor	4.0 grams/ bhp-hr	2.5 grams/ bhp-hr
PM10 Factor	0.1 grams/ bhp-hr	0.1 grams/ bhp-hr

Calculations

Annual ROG, NOx, and PM10 Emission Reductions from the Cleaner Engines (Engine Reductions) =

[Main Fuel * (Main EF Before – Main EF After) + Aux Fuel * (Aux EF Before – Aux EF After)]* 18.5/454

ROG: 0

NOx: [5,000 * (4.0 – 2.5) + 2,500 * (4.0 – 2.5)] * 18.5/454 = **458 lbs. per year reduced**

PM10: [5,000 * (0.1 – 0.1) + 2,500 * (0.1 – 0.1)] * 18.5/454 = **0 lbs. per year reduced**

Annual PM10 Emission Reductions from Sweeping (Sweeping Reductions) =

Miles Swept * 0.05

PM10: 10,000 * 0.05 = **500 lbs. per year reduced**

Annual Emission Reductions (ROG, NOx, and PM10) =

= Engine Reductions + Sweeping Reductions

ROG = 0 lbs. per year reduced

NOx = 458 lbs. per year reduced

PM10 = 500 lbs. per year reduced

Capital Recovery Factor (CRF) = $\frac{(1 + i)^n(i)}{(1 + i)^n - 1}$ *where: i = discount rate (assume 5 percent)*

n = project life (10 years)

(From Table 8)

$$CRF = \frac{(1 + .05)^{10}(.05)}{(1 + .05)^{10} - 1} = 0.13$$

Cost-Effectiveness of Funding Dollars = (CRF * Funding)/(ROG + NOx + PM10)

=(0.13 * 40,000) / (958)

= $ 5 per lb.

FOR CMAQ PROJECTS ONLY:

Once emissions reductions have been calculated, add them together (0+ 458 + 500 = 958) and convert emissions reductions to kg/day: $\frac{\textit{lbs. per year}}{\textit{2.2 lbs./kg * 365 days/year}} = \frac{958}{2.2 * 365} =$ ***1 kg/day***